SATELLITE PACKET BROADCASTING
TO VERY SMALL EARTH STATIONS

BY

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THE ALOHA SYSTEM

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Abstract

In this paper we analyze the thruput of an ALOHA channel when compared to that of a conventional point-to-point channel of the same average power. This analysis is of interest in the case of a satellite information system employing thousands of small earth stations. For a satellite system the fundamental limitation in the downlink is the average power available in the satellite transponder rather than the peak power. Our results show that in the limit of large numbers of small earth stations the ALOHA thruput approaches 100% of the point-to-point capacity. Thus the multiple access capability and the complete connectivity (in the topological sense) of an ALOHA channel can be obtained at no price in average thruput. Furthermore, since our results suggest the use of higher peak power in the satellite transponder (while the average power is kept constant) the small earth stations may use smaller antennas and simpler receivers and modems than would be necessary in a conventional system.

B75-25

1. INTRODUCTION

The use of ALOHA channels of various types has been analyzed extensively by a number of authors [1] - [8]. For the case of an information network with a large number of users having high peak to average data rates the thruput of such channels has been compared to that of the equivalent point-to-point channel of the same peak data rate. The maximum thruput has been shown to vary between 18% and 75% or higher of the equivalent point-to-point channel. The former value is typical of a system employing many small remote interactive units [1] while the latter value applies for the case of a channel used by remote interactive units together with a number of remote units which from time to time, transfer large data files. Thus the price paid for the multiple access capability and the packet broadcasting capability of an ALOHA channel is a decrease in the average data rate (but not the peak data rate) of the channel.

Because ALOHA channels operate in a burst mode with a duty cycle significantly less than one, the average power of the channel can be well below the peak power - just as the average data rate is below the peak data rate. This effect has been noted before [8], but the thruput analysis of ALOHA channels has previously been compared only to that of a conventional point-to-point channel of the same peak power.

In this paper we analyze the thruput of an ALOHA channel when compared to that of a conventional point-to-point channel of the same average power. This analysis is of interest in the case of a satellite information system employing thousands of small earth stations. For a satellite system the

fundamental limitation in the downlink is the average power available in
the satellite transponder rather than the peak power. Our results show
that in the limit of large numbers of small earth stations the ALOHA thruput
approaches 100% of the point-to-point capacity. Thus the multiple access
capability and the complete connectivity (in the topological sense) of an
ALOHA channel can be obtained at no price in average thruput. Furthermore,
since our results suggest the use of higher peak power in the satellite
transponder (while the average power is kept constant) the small earth
stations may use smaller antennas and simpler receivers and modems than
would be necessary in a conventional system.

In existing satellite systems the TWT output power in each transponder
cannot be varied dynamically. In such systems the advantages implied by our
analysis may be realized by frequency division sharing a single transponder
among several voice users and a single channel, operating in an ALOHA mode
or some other burst mode and occupying a frequency band equivalent to one
or more voice users. The type of operation implied by our analysis also
suggests investigation of high peak power satellite burst transponders
(perhaps employing power devices similar to those used in radar systems)
for use in information systems composed of large numbers of ultra-small
earth stations.

2. ALOHA CHANNELS

The basic equation defining the operation of an ALOHA channel [1]
provides a relation between S, the channel thruput and G, the channel traffic.

Roughly speaking S is the average data which is actually transmitted by the channel, normalized with respect to the continuous data rate realizable by the channel when used in a fixed point-to-point connection; G is the average data rate inserted into the channel by the many different users of the channel (some of which does not get thru the channel, due to interference among users) normalized in the same way. In an ALOHA channel this relation is [1]

$$S = Ge^{-2G} \qquad (1)$$

while in a slotted ALOHA channel, we have (8)

$$S = Ge^{-G} \qquad (2)$$

These relations are plotted in Figure 1.

The power actually transmitted in the channel will depend upon G in some manner. For the case of most interest we will analyze an ALOHA channel using a transponder (such as in the satellite case) and we will be concerned with the power out of the transponder. We shall deal with the case of a hard limiting transponder as well as the case of the linear transponder. We note however that in some circumstances (notably that of small, battery powered remote units) we might also be interested in the power out of the remote units. In these cases our results for the linear transponder apply without change.
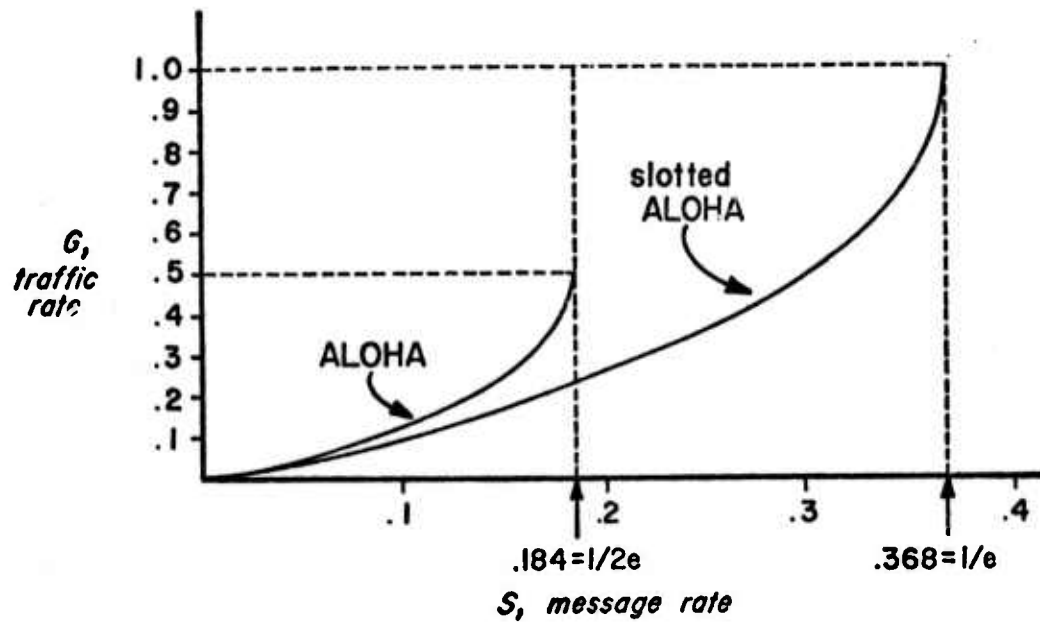
Figure 1.   TRAFFIC RATE VS MESSAGE RATE FOR A
PURE ALOHA CHANNEL AND A SLOTTED ALOHA CHANNEL

3. SATELLITE CAPACITY

The capacity of a satellite channel can be calculated by the classical Shannon equation

$$C = W\log\left(1+\frac{P}{N}\right) \tag{3}$$

where C is the capacity in bits (if the log is a base two logarithm), W is the channel bandwidth, P is the average received signal power at the earth station and N is the average noise power at the earth station. Equation (3) expresses the capacity of the satellite channel under the assumption that the transponder transmits continuously.

If the channel is used in burst mode as an ALOHA channel the transponder will emit power only when a data burst occurs and the average power out of the transponder will be less than the burst power. Let D be the ratio of the average power transmitted to the power transmitted during a data burst. For a linear transponder D will equal the channel traffic, G, and for a hard limiting transponder D will equal the duty cycle of the channel. For both the unslotted [1] and slotted [8] ALOHA channel the duty cycle is $1-e^{-G}$. Thus, for a linear transponder*

$$D = G \tag{4a}$$

While for a hard limiting transponder

$$D = 1-e^{-G} \tag{4b}$$

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* Our analysis is of signigicance only for G < 1. The analysis is formally correct however for all G, even though the designation of the power transmitted during bursts as "peak power" becomes inappropriate for the linear transponder case when G > 1. (In such a situation the "peak power" is less than the average power.)

Note that in the case of a hard limiting transponder with small values of channel traffic, the duty cycle approaches that of a linear transponder.

If we retain P as the notation for the average signal power received at the earth station, the power received during a data burst will be P/D. Thus Equation (3) should be modified in two ways:

a. We replace W by SW to account for the fact that the channel is only used intermittently.

b. We replace P in (3) by P/D, to keep the average power of the channel fixed at P.

We should note that when we make these changes in (3) we are assuming that the packet length of the system is long enough so that the asymptotic assumptions which are used to derive (3) still apply. In practice this is not a problem.

With these two changes then we have four different cases:

1. unslotted channel, linear transponder

$$C_1 = Ge^{-2G}W\log\left(1+\frac{P}{GN}\right) \qquad (5a)$$

2. unslotted channel, limiting transponder

$$C_2 = Ge^{-2G}W\log\left(1+\frac{P}{(1-e^{-G})N}\right) \qquad (5b)$$

3. slotted channel, linear transponder

$$C_3 = Ge^{-G}W\log\left(1+\frac{P}{GN}\right) \qquad (5c)$$

4. slotted channel, limiting transponder

$$C_4 = Ge^{-G}W\log\left(1+\frac{P}{(1-e^{-G})N}\right) \qquad (5d)$$

We have written two programs in basic to calculate the normalized capacities, $\frac{C_i}{C}$ for i=1,2,3,4, for different values of P/N the signal-to-noise

ratio of the earth station when the transponder operates continuously.
These programs are given in Appendix A as CLIN and CHARD, together with a
printout of the values of the normalized capacities. The normalized capacities
are plotted in Figures 2, 3, 4 and 5 for P/N equal to -20, -10, 0, 10, 20 db.
Of particular interest in these curves is the fact that the highest values
of C_i/C occur just where we would want them to occur - for small values of
channel traffic (G) and for small earth stations (low P/N). In the limit
we have (for a fixed value of G)

$$\lim_{P/N \to 0} \frac{C_i}{C} = \frac{S}{D} \qquad i=1,2,3,4 \qquad (6)$$
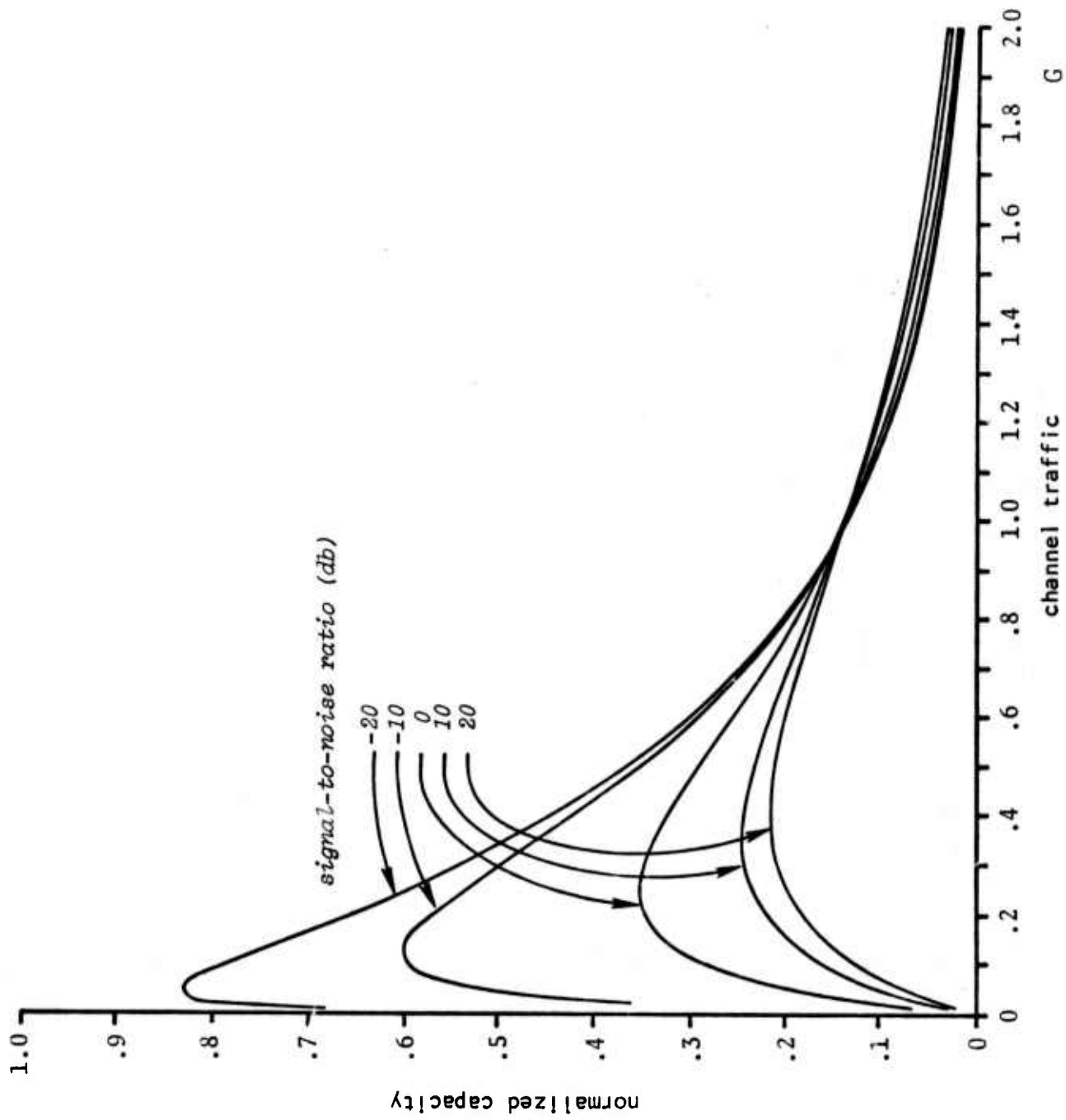
Figure 2. LINEAR TRANSPONDER; UNSLOTTED CHANNEL
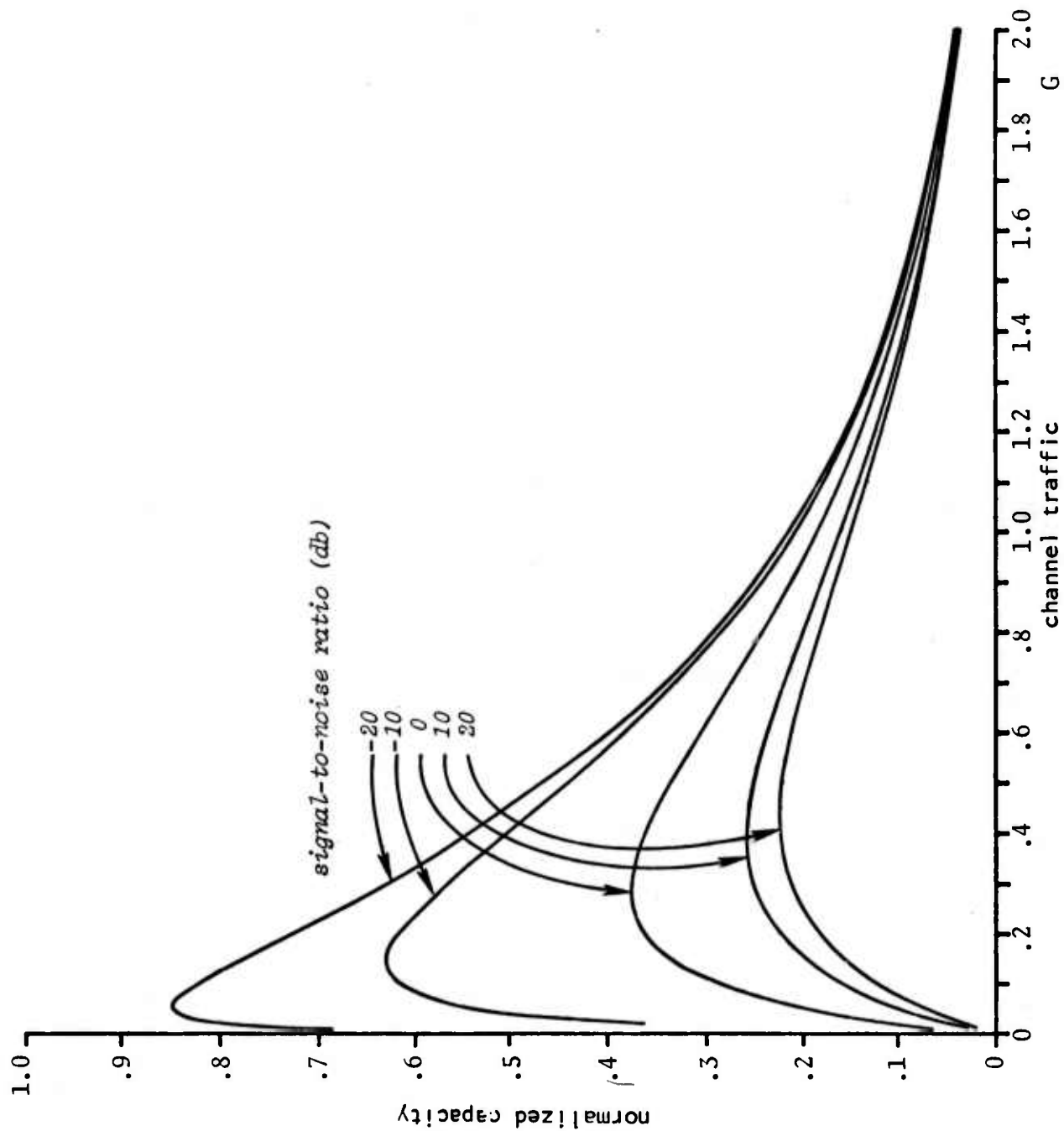
Figure 3. LIMITING TRANSPONDER; UNSLOTTED CHANNEL
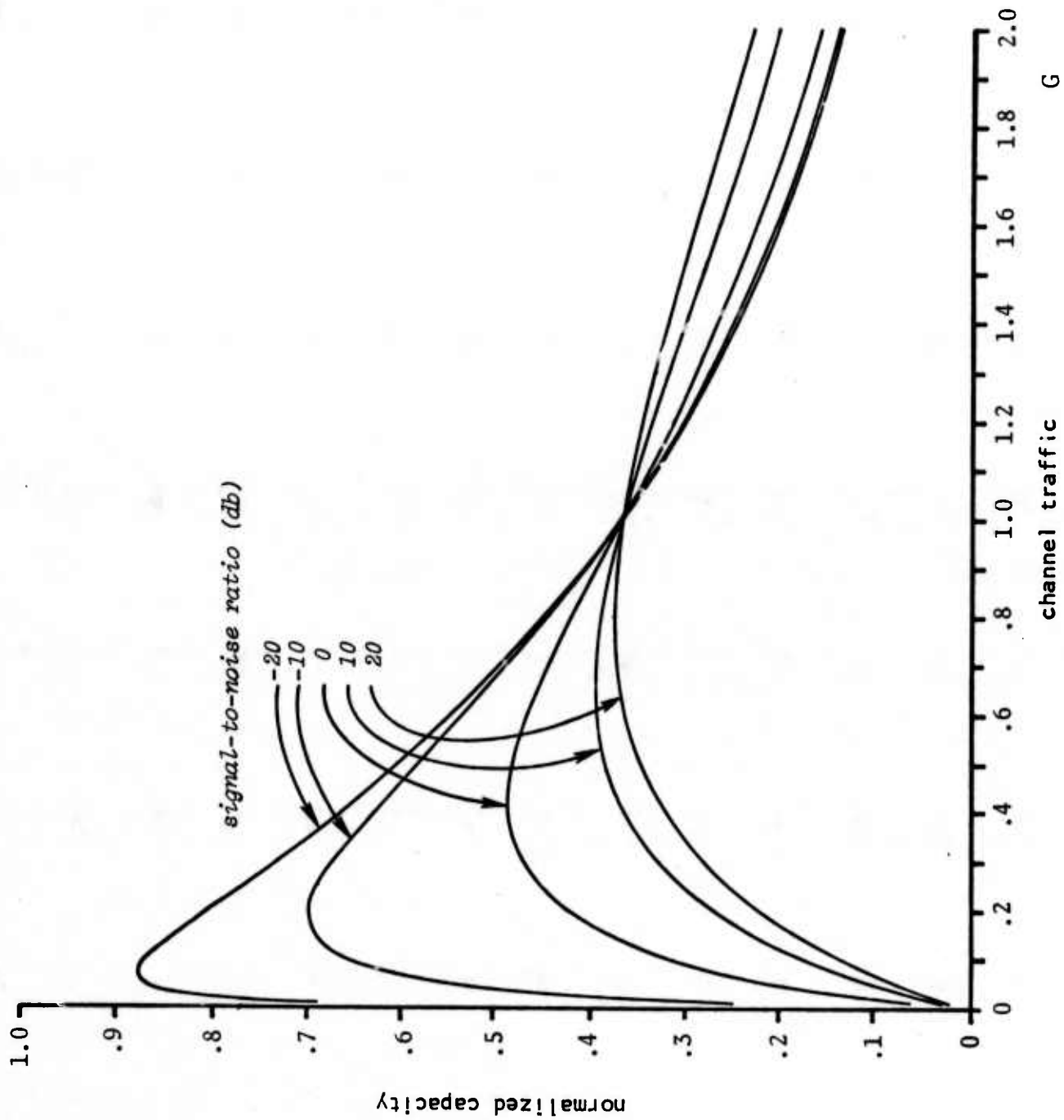
Figure 4. LINEAR TRANSPONDER; SLOTTED CHANNEL
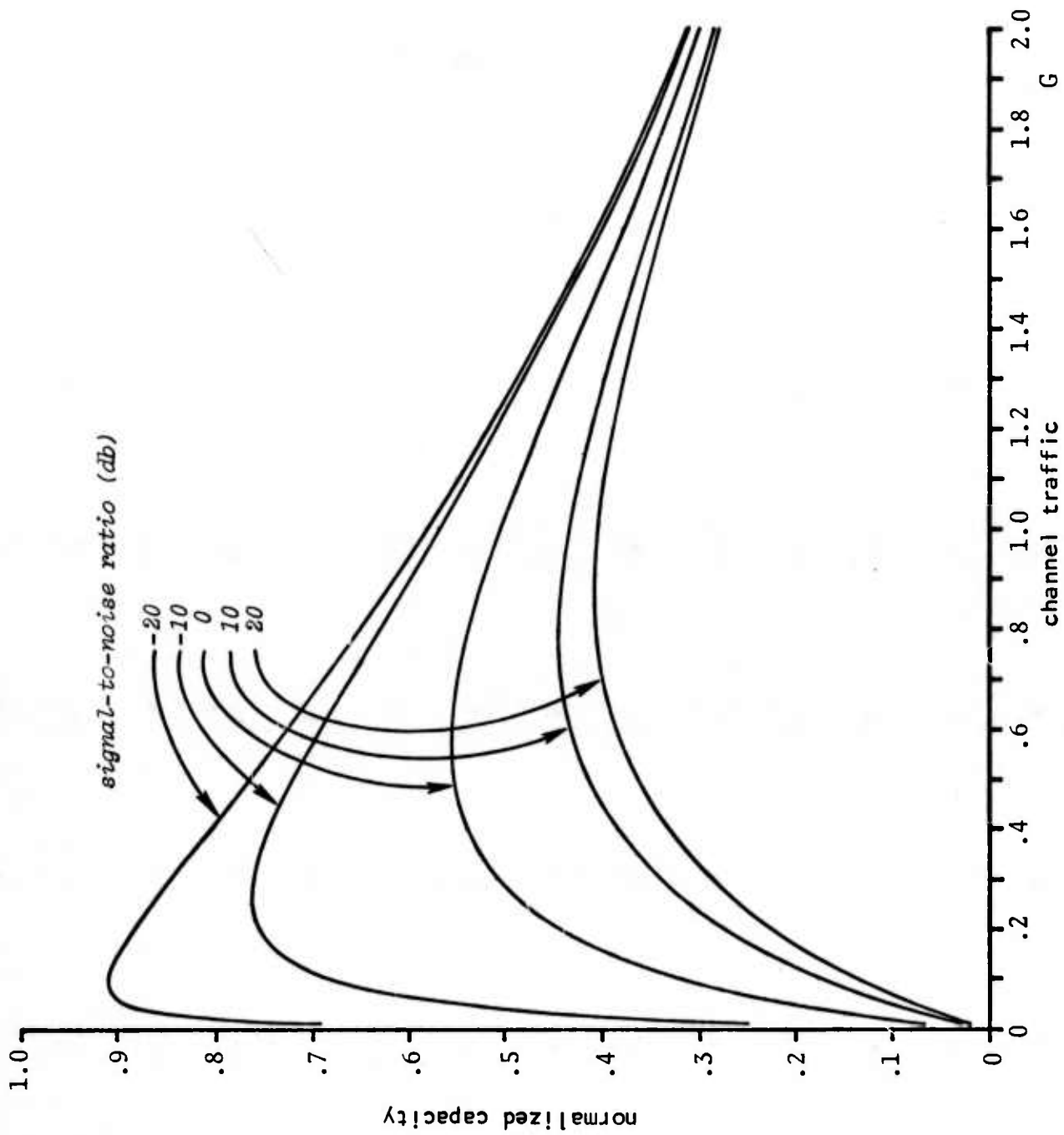
Figure 5.   LIMITING TRANSPONDER; SLOTTED CHANNEL

so that

    1. unslotted channels, linear transponder

$$\lim_{P/N \to 0} \frac{C_1}{C} = e^{-2G} \tag{7a}$$

    2. unslotted channels, limiting transponder

$$\lim_{P/N \to 0} \frac{C_2}{C} = \frac{Ge^{-2G}}{\left(1-e^{-G}\right)} \tag{7b}$$

    3. slotted channel, linear transponder

$$\lim_{P/N \to 0} \frac{C_3}{C} = e^{-G} \tag{7c}$$

    4. slotted channel, limiting transponder

$$\lim_{P/N \to 0} \frac{C_4}{C} = \frac{Ge^{-G}}{\left(1-e^{-G}\right)} \tag{7d}$$

and in all cases

$$\lim_{G \to 0} \quad \lim_{P/N \to 0} \quad \frac{C_i}{C} = 1 \tag{8}$$

Thus this multiplexing technique allows a network of small inexpensive earth stations to achieve the maximum value of channel capacity, at the same time providing complete connectivity and multiple access capability.

APPENDIX A

```
00010 FILES A
00020 SCRATCH #1
00030 : ##.##     ##.###   ##.###   ##.###   ##.###   ##.###
00040 FOR S=1 TO 2
00050 PRINT #1, ,"  FOR A LINEAR TRANSPONDER"
00060 IF S=2 THEN 90
00070 PRINT #1, "   NORMALIZED CAPACITY OF THE SLOTTED ALOHA CHANNEL"
00080 GO TO 100
00090 PRINT #1, "   NORMALIZED CAPACITY OF THE UNSLOTTED ALOHA CHANNEL"
00100 PRINT #1,
00110 PRINT #1,
00120 PRINT #1, ,"SIGNAL TO NOISE RATIO (DB)"
00130 PRINT #1, "CHANNEL"
00140 PRINT #1, "TRAFFIC";
00150 PRINT #1, "      -20";"    -10";"      0 ";"     10 ";"     20"
00160 PRINT #1,
00170 FOR G=.01 TO 2.001 STEP .01
00180 IF G<.205 THEN 210
00190 IF (G-.05*INT((G+.001)/.05))<.005 THEN 210
00200 GO TO 300
00210 FOR K=1 TO 5
00220 LET A=10**(K-3)
00230 LET F1=EXP(-(S*G))
00240 LET F2=LOG(1+(A/G))
00250 LET F3=LOG(1+A)
00260 LET F=G*F1*F2/F3
00270 LET H(K)=F
00280 NEXT K
00290 PRINT #1, USING 30,G,H(1),H(2),H(3),H(4),H(5)
00300 NEXT G
00310 FOR T= 1 TO 5
00320 PRINT #1,
00330 NEXT T
00340 NEXT S
00350 END
```

FOR A LINEAR TRANSPONDER
NORMALIZED CAPACITY OF THE SLOTTED ALOHA CHANNEL

CHANNEL TRAFFIC	SIGNAL TO NOISE RATIO (DB)				
	-20	-10	0	10	20
0.01	0.690	0.249	0.066	0.029	0.020
0.02	0.799	0.369	0.111	0.051	0.036
0.03	0.842	0.448	0.149	0.071	0.051
0.04	0.862	0.505	0.181	0.089	0.065
0.05	0.871	0.548	0.209	0.105	0.078
0.06	0.875	0.581	0.234	0.121	0.091
0.07	0.876	0.608	0.257	0.135	0.103
0.08	0.874	0.628	0.277	0.149	0.114
0.09	0.871	0.645	0.296	0.162	0.125
0.10	0.867	0.658	0.313	0.174	0.135
0.11	0.862	0.669	0.329	0.186	0.145
0.12	0.856	0.677	0.343	0.197	0.155
0.13	0.850	0.683	0.356	0.207	0.164
0.14	0.844	0.688	0.368	0.217	0.173
0.15	0.837	0.692	0.379	0.227	0.182
0.16	0.831	0.695	0.390	0.236	0.190
0.17	0.824	0.696	0.399	0.245	0.198
0.18	0.817	0.697	0.408	0.253	0.206
0.19	0.810	0.697	0.416	0.261	0.213
0.20	0.803	0.697	0.423	0.269	0.221
0.25	0.767	0.687	0.452	0.302	0.253
0.30	0.732	0.671	0.470	0.328	0.280
0.35	0.698	0.650	0.480	0.348	0.302
0.40	0.665	0.628	0.485	0.364	0.321
0.45	0.634	0.604	0.484	0.376	0.336
0.50	0.604	0.580	0.481	0.385	0.348
0.55	0.575	0.556	0.474	0.391	0.358
0.60	0.547	0.533	0.466	0.394	0.365
0.65	0.521	0.509	0.456	0.396	0.371
0.70	0.496	0.487	0.445	0.395	0.374
0.75	0.472	0.465	0.433	0.393	0.376
0.80	0.449	0.444	0.421	0.390	0.377
0.85	0.427	0.424	0.408	0.386	0.376
0.90	0.406	0.404	0.394	0.381	0.374
0.95	0.387	0.386	0.381	0.375	0.371
1.00	0.368	0.368	0.368	0.368	0.368
1.05	0.350	0.351	0.355	0.361	0.364
1.10	0.333	0.334	0.342	0.353	0.359
1.15	0.317	0.319	0.329	0.345	0.353
1.20	0.301	0.304	0.316	0.337	0.347
1.25	0.287	0.289	0.304	0.328	0.341
1.30	0.273	0.275	0.292	0.320	0.334
1.35	0.260	0.262	0.280	0.311	0.327
1.40	0.247	0.250	0.268	0.302	0.320
1.45	0.235	0.238	0.257	0.293	0.313
1.50	0.223	0.227	0.247	0.284	0.306
1.55	0.213	0.216	0.236	0.276	0.298
1.60	0.202	0.205	0.226	0.267	0.291
1.65	0.192	0.196	0.217	0.258	0.283
1.70	0.183	0.186	0.207	0.250	0.275
1.75	0.174	0.177	0.198	0.241	0.268
1.80	0.166	0.169	0.190	0.233	0.260
1.85	0.158	0.161	0.181	0.225	0.253
1.90	0.150	0.153	0.173	0.217	0.245
1.95	0.143	0.146	0.166	0.210	0.238
2.00	0.136	0.139	0.158	0.202	0.231

FOR A LINEAR TRANSPONDER
NORMALIZED CAPACITY OF THE UNSLOTTED ALOHA CHANNEL

SIGNAL TO NOISE RATIO (DB)

CHANNEL TRAFFIC	-20	-10	0	10	20
0.01	0.683	0.247	0.065	0.028	0.020
0.02	0.783	0.361	0.109	0.050	0.035
0.03	0.817	0.435	0.144	0.068	0.050
0.04	0.828	0.485	0.174	0.085	0.063
0.05	0.829	0.521	0.199	0.100	0.075
0.06	0.824	0.548	0.220	0.114	0.086
0.07	0.817	0.567	0.239	0.126	0.096
0.08	0.807	0.580	0.256	0.137	0.105
0.09	0.796	0.589	0.270	0.148	0.114
0.10	0.784	0.595	0.283	0.158	0.123
0.11	0.772	0.599	0.294	0.166	0.130
0.12	0.759	0.600	0.304	0.175	0.138
0.13	0.747	0.600	0.313	0.182	0.144
0.14	0.734	0.598	0.320	0.189	0.151
0.15	0.721	0.596	0.327	0.195	0.157
0.16	0.708	0.592	0.332	0.201	0.162
0.17	0.695	0.587	0.337	0.206	0.167
0.18	0.682	0.582	0.341	0.211	0.172
0.19	0.670	0.576	0.344	0.216	0.176
0.20	0.657	0.570	0.347	0.220	0.181
0.25	0.598	0.535	0.352	0.235	0.197
0.30	0.543	0.497	0.348	0.243	0.207
0.35	0.492	0.458	0.338	0.245	0.213
0.40	0.446	0.421	0.325	0.244	0.215
0.45	0.404	0.385	0.309	0.240	0.214
0.50	0.366	0.352	0.292	0.234	0.211
0.55	0.332	0.321	0.274	0.226	0.207
0.60	0.300	0.292	0.256	0.216	0.201
0.65	0.272	0.266	0.238	0.207	0.194
0.70	0.246	0.242	0.221	0.196	0.186
0.75	0.223	0.220	0.205	0.186	0.178
0.80	0.202	0.200	0.189	0.175	0.169
0.85	0.183	0.181	0.174	0.165	0.161
0.90	0.165	0.164	0.160	0.155	0.152
0.95	0.150	0.149	0.147	0.145	0.144
1.00	0.135	0.135	0.135	0.135	0.135
1.05	0.122	0.123	0.124	0.126	0.127
1.10	0.111	0.111	0.114	0.117	0.119
1.15	0.100	0.101	0.104	0.109	0.112
1.20	0.091	0.091	0.095	0.101	0.105
1.25	0.082	0.083	0.087	0.094	0.098
1.30	0.074	0.075	0.079	0.087	0.091
1.35	0.067	0.068	0.073	0.081	0.085
1.40	0.061	0.062	0.066	0.074	0.079
1.45	0.055	0.056	0.060	0.069	0.073
1.50	0.050	0.051	0.055	0.063	0.068
1.55	0.045	0.046	0.050	0.058	0.063
1.60	0.041	0.041	0.046	0.054	0.059
1.65	0.037	0.038	0.042	0.050	0.054
1.70	0.033	0.034	0.038	0.046	0.050
1.75	0.030	0.031	0.034	0.042	0.047
1.80	0.027	0.028	0.031	0.039	0.043
1.85	0.025	0.025	0.029	0.035	0.040
1.90	0.022	0.023	0.026	0.033	0.037
1.95	0.020	0.021	0.024	0.030	0.034
2.00	0.018	0.019	0.021	0.027	0.031

```
00010 FILES B
00020 SCRATCH #1
00030 : ##.##    ##.###  ##.###  ##.###  ##.###  ##.###
00040 FOR S=1 TO 2
00050 PRINT #1, ,"FOR A HARD LIMITING TRANSPONDER"
00060 IF S=2 THEN 90
00070 PRINT #1, "   NORMALIZED CAPACITY OF THE SLOTTED ALOHA CHANNEL"
00080 GO TO 100
00090 PRINT #1, "   NORMALIZED CAPACITY OF THE UNSLOTTED ALOHA CHANNEL"
00100 PRINT #1,
00110 PRINT #1,
00120 PRINT #1, ,"SIGNAL TO NOISE RATIO (DB)"
00130 PRINT #1, "CHANNEL"
00140 PRINT #1, "TRAFFIC";
00150 PRINT #1 "      -20";"     -10";"      0 ";"     10 ";"     20"
00160 PRINT #1
00170 FOR G=.01 TO 2.001 STEP .01
00180 IF G<.205 THEN 210
00190 IF (G-.05*INT((G+.001)/.05))<.005 THEN 210
00200 GO TO 300
00210 FOR K=1 TO 5
00220 LET A=10**(K-3)
00230 LET F1=EXP(-(S*G))
00240 LET F2=LOG(1+(A/(1-EXP(-G))))
00250 LET F3=LOG(1+A)
00260 LET F=G*F1*F2/F3
00270 LET H(K)=F
00280 NEXT K
00290 PRINT #1, USING 30, G,H(1),H(2),H(3),H(4),H(5)
00300 NEXT G
00310 FOR T= 1 TO 5
00320 PRINT #1,
00330 NEXT T
00340 NEXT S
00350 END
```

FOR A HARD LIMITING TRANSPONDER
NORMALIZED CAPACITY OF THE SLOTTED ALOHA CHANNEL

CHANNEL	SIGNAL TO NOISE RATIO (DB)				
TRAFFIC	-20	-10	0	10	20
0.01	0.692	0.250	0.066	0.029	0.020
0.02	0.805	0.370	0.111	0.051	0.036
0.03	0.853	0.451	0.149	0.071	0.051
0.04	0.877	0.511	0.182	0.089	0.065
0.05	0.892	0.557	0.211	0.106	0.079
0.06	0.900	0.593	0.236	0.121	0.091
0.07	0.905	0.622	0.260	0.136	0.103
0.08	0.908	0.646	0.281	0.150	0.115
0.09	0.909	0.665	0.301	0.163	0.126
0.10	0.909	0.682	0.319	0.176	0.136
0.11	0.908	0.696	0.336	0.188	0.147
0.12	0.906	0.707	0.351	0.199	0.156
0.13	0.904	0.717	0.366	0.210	0.166
0.14	0.902	0.726	0.379	0.221	0.175
0.15	0.900	0.733	0.391	0.231	0.184
0.16	0.897	0.739	0.403	0.240	0.193
0.17	0.894	0.744	0.414	0.250	0.201
0.18	0.890	0.748	0.424	0.258	0.209
0.19	0.887	0.752	0.434	0.267	0.217
0.20	0.884	0.755	0.443	0.275	0.224
0.25	0.865	0.762	0.480	0.311	0.258
0.30	0.846	0.761	0.507	0.341	0.287
0.35	0.825	0.755	0.526	0.365	0.311
0.40	0.805	0.745	0.539	0.385	0.332
0.45	0.785	0.734	0.548	0.401	0.350
0.50	0.765	0.721	0.553	0.414	0.364
0.55	0.745	0.706	0.555	0.424	0.376
0.60	0.725	0.692	0.555	0.432	0.386
0.65	0.706	0.676	0.553	0.437	0.393
0.70	0.687	0.661	0.549	0.440	0.399
0.75	0.668	0.645	0.543	0.442	0.403
0.80	0.650	0.629	0.537	0.443	0.406
0.85	0.632	0.614	0.530	0.442	0.407
0.90	0.615	0.598	0.521	0.440	0.407
0.95	0.597	0.582	0.513	0.437	0.406
1.00	0.580	0.567	0.503	0.433	0.404
1.05	0.564	0.552	0.494	0.428	0.401
1.10	0.548	0.537	0.484	0.423	0.398
1.15	0.532	0.522	0.474	0.418	0.394
1.20	0.516	0.507	0.463	0.411	0.389
1.25	0.501	0.493	0.453	0.405	0.384
1.30	0.486	0.479	0.442	0.398	0.379
1.35	0.472	0.465	0.431	0.390	0.373
1.40	0.457	0.451	0.421	0.383	0.366
1.45	0.444	0.438	0.410	0.375	0.360
1.50	0.430	0.425	0.399	0.367	0.353
1.55	0.417	0.413	0.389	0.359	0.346
1.60	0.404	0.400	0.379	0.351	0.339
1.65	0.392	0.388	0.368	0.343	0.331
1.70	0.380	0.376	0.358	0.335	0.324
1.75	0.368	0.365	0.348	0.326	0.317
1.80	0.356	0.353	0.338	0.318	0.309
1.85	0.345	0.342	0.328	0.310	0.302
1.90	0.334	0.331	0.319	0.302	0.294
1.95	0.323	0.321	0.309	0.294	0.297
2.00	0.313	0.311	0.300	0.286	0.279

FOR A HARD LIMITING TRANSPONDER
NORMALIZED CAPACITY OF THE UNSLOTTED ALOHA CHANNEL

SIGNAL TO NOISE RATIO (DB)

CHANNEL TRAFFIC	-20	-10	0	10	20
0.01	0.685	0.247	0.065	0.028	0.020
0.02	0.789	0.363	0.109	0.050	0.036
0.03	0.828	0.438	0.145	0.069	0.050
0.04	0.843	0.491	0.175	0.085	0.063
0.05	0.848	0.529	0.200	0.101	0.075
0.06	0.848	0.558	0.223	0.114	0.086
0.07	0.844	0.580	0.242	0.127	0.096
0.08	0.838	0.596	0.260	0.139	0.106
0.09	0.830	0.608	0.275	0.149	0.115
0.10	0.822	0.617	0.289	0.159	0.123
0.11	0.813	0.623	0.301	0.168	0.131
0.12	0.804	0.627	0.311	0.177	0.139
0.13	0.794	0.630	0.321	0.185	0.146
0.14	0.784	0.631	0.329	0.192	0.152
0.15	0.774	0.631	0.337	0.199	0.158
0.16	0.764	0.630	0.344	0.205	0.164
0.17	0.754	0.628	0.349	0.211	0.169
0.18	0.744	0.625	0.354	0.216	0.174
0.19	0.734	0.622	0.359	0.221	0.179
0.20	0.723	0.618	0.363	0.225	0.183
0.25	0.674	0.593	0.374	0.242	0.201
0.30	0.626	0.564	0.375	0.253	0.213
0.35	0.582	0.532	0.371	0.257	0.219
0.40	0.540	0.500	0.362	0.258	0.223
0.45	0.501	0.468	0.350	0.256	0.223
0.50	0.464	0.437	0.336	0.251	0.221
0.55	0.430	0.408	0.320	0.245	0.217
0.60	0.398	0.380	0.305	0.237	0.212
0.65	0.369	0.353	0.289	0.228	0.205
0.70	0.341	0.328	0.272	0.219	0.198
0.75	0.316	0.305	0.257	0.209	0.190
0.80	0.292	0.283	0.241	0.199	0.182
0.85	0.270	0.262	0.226	0.189	0.174
0.90	0.250	0.243	0.212	0.179	0.165
0.95	0.231	0.225	0.198	0.169	0.157
1.00	0.213	0.209	0.185	0.159	0.149
1.05	0.197	0.193	0.173	0.150	0.140
1.10	0.182	0.179	0.161	0.141	0.132
1.15	0.168	0.165	0.150	0.132	0.125
1.20	0.155	0.153	0.140	0.124	0.117
1.25	0.144	0.141	0.130	0.116	0.110
1.30	0.132	0.130	0.120	0.108	0.103
1.35	0.122	0.12.	0.112	0.101	0.097
1.40	0.113	0.111	0.104	0.094	0.090
1.45	0.104	0.103	0.096	0.088	0.084
1.50	0.096	0.095	0.089	0.082	0.079
1.55	0.089	0.088	0.083	0.076	0.073
1.60	0.082	0.081	0.076	0.071	0.068
1.65	0.075	0.075	0.071	0.066	0.064
1.70	0.069	0.069	0.065	0.061	0.059
1.75	0.064	0.063	0.060	0.057	0.055
1.80	0.059	0.058	0.056	0.053	0.051
1.85	0.054	0.054	0.052	0.049	0.047
1.90	0.050	0.050	0.048	0.045	0.044
1.95	0.046	0.046	0.044	0.042	0.041
2.00	0.042	0.042	0.041	0.039	0.038

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